高次の積分方程式法による高精度電磁誘導フォワード計算コードの開発

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Novel “high-order” integral equation solver for electromagnetic sounding problems

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Electromagnetic (EM) methods are widely used in geophysics to model the subsurface electrical conductivity distribution. Conductivity is affected by rock type and composition, temperature, and fluid/melt content and thus can be used in various engineering and industrial problems such as detection of hydrocarbon (low-conductive) and geothermal or ore (high-conductive) reservoirs. Measured electrical and/or magnetic fields are further interpreted via calculations using a given three-dimensional model of the conductivity distribution.

However, still 3-D EM numerical simulations - which are a core part of any 3-D data analysis - with realistic levels of complexity, accuracy and spatial detail remain challenging from the computational point of view. To overcome this challenge the first-ever “high-order” solver for the volumetric integral equations (IE) of electrodynamics is presented. In contrast to previous IE solvers based on piece-wise constant approximation of the fields inside anomaly, the novel one is based on the piece-wise polynomial representation. Utilization of Galerkin method for constructing the system of linear equations provides not only guaranteed convergence of the iterative numerical solution, but also ensures that the system matrix is well-conditioned irrespective of the polynomials order.

The main computational challenge of presented approach is the computation of matrix coefficients i.e. the double volumetric integrals of the product between Green’s function and polynomials. These challenge has been overcame by the generalization of the “quasi-analytical” approach proposed by first author for his previous IE solver, based on piece-wise constant approximation.

The numerical experiments demonstrate the possibility to decrease number of unknowns by several orders of magnitude with corresponding memory saving and speed up.